PNEUMATIC CONVEYOR For DISTRIBUTING FARM FEED

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Pneumatic Conveyor For Distributing Farm Feed

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Automation and better management are the best ways to reduce costs in any business, particularly one in which livestock and poultry are produced. Handling of materials and wastes and the feeding of animals account for much of the labor required on livestock farms. Because feed is usually handled on a regular schedule, the development of a method to handle it automatically provides a useful device for all livestock producers.

Automatic handling of feed requires a system that can move materials from storage and blend, process, and transport or distribute them to animals or poultry without operator supervision. Most of the steps involved in the handling of feed—moving from storage, blending, and processing—occur within small areas and generally require movement of material over very short distances.

The transportation or distribution of feed or feed materials can involve long distances for which the use of wheeled vehicles is most economical. However, the movement of these items over a distance of several hundred feet or less lends itself to the use of automatic conveyors that operate concurrently with other parts of the feed-preparation routine. Properly designed automatic conveyors for the movement of feed can save time and labor in most livestock enterprises.

Feed can be delivered to animals by either an auger conveyor or by a pneumatic conveyor while the materials are being blended and processed. For moving feed less than 100 feet, the auger conveyor is probably the more economical. However, installation of auger conveyors in existing buildings can be complicated. Pneumatic conveyors are easier to install and less difficult to maintain because all of the operating equipment is in one location. Therefore, the pneumatic conveyor may be more desirable for conveying materials over distances in excess of 100 feet. The initial cost of a medium-pressure pneumatic conveyor is equal to that of a 300- to 400-foot 4-inch auger conveyor.

INDUSTRIAL PNEUMATIC CONVEYORS

Pneumatic conveyor systems are usually grouped in three classifications: (1) High-volume low-pressure like the conventional dust-conveying system (less than 3 p.s.i.), (2) low-volume medium-pressure (3 to 20 p.s.i.), and (3) low-volume high-pressure (more than 20 p.s.i.). The low-volume medium-pressure system fits farm needs the best for the following reasons: (*a*) The air volume and pressure requirements are modest and can be satisfied with a low-cost compressor of small size; (*b*) the feed is blown through small-diameter pipe that can be easily installed overhead or underground and made to conform to the shape of the building or facility in which it is to be installed; (*c*) the system can be used to convey feed for distances of approximately 500 feet; and (*d*) because of the low volume of air, feed is easily collected at the discharge point with a minimum of dust.

Industrial plants have used low-volume medium-pressure pneumatic conveyors for many years to transport cement, flour, powdered coal, and other particulate materials. After World War II, the use of this method of conveying increased rapidly, primarily because of the increased emphasis on automation. However, the systems available commercially were too large and too expensive for use in conveying feed. A system using 1½-inch i.d. (inside diameter) pipe and a conveying rate of approximately 4 tons per hour was the smallest industrial system available. It used a star wheel air lock to place the conveyed material into the pneumatic system. The capacity of the 1½-inch system was higher than is needed for farm use, and the star wheel air lock was a major factor in its high cost. The air lock for 1½-inch pipe costs from $300 to $1,000, depending upon the type.

DEVELOPING A PNEUMATIC CONVEYOR FOR FARM USE

Conveyor With Star Wheel Air Lock

The star wheel air lock was used by the authors to develop controls and determine pressure losses while designing a conveyor system suitable for farm use. The total pressure required of the conveying compressor is the total of all pressure drops in the conveying system.

After the basic information had been collected, a medium-pressure pneumatic system for conveying farm feed was built and installed on a farm in Illinois. The farm was raising 26,000 caponettes and 14,000 turkeys a year. Since then it has converted its production entirely to turkeys and is raising 26,000 of them a year. The pneumatic system installed was capable of automatically delivering a single ration to any one of four locations without operator attention. This system used a star feeder valve to introduce ground feed into a 1-inch pneumatic conveying line. High cost prevented wide use of the medium-pressure pneumatic conveyor equipped with the star wheel air lock.

Successful auger air locks were known, but they were not capable of maintaining the needed air seal when material was not being fed into the conveyor. In addition, auger air locks were not able to operate over a wide range of input rates without requiring adjustment of the auger speed.

Conveyor With Auger Injector Air Lock

Work was begun to develop an auger injector air lock that would use a labyrinth seal in which the conveyed material made its own air seal, and that would be less expensive than the star wheel air lock. The first successful design used two augers that pushed the conveyed material upward into the conveying line. The vertical auger ended 4 inches short of the junction with the conveying line. Above the end of this auger was a tapered section of tubing that served as the plugging chamber. It acted as the air lock and prevented air escaping from the conveying line when no new material was being fed into it. The plugging chamber flared one-half inch in diameter in its 4-inch length. A smaller flare worked nearly as well, and larger ones worked no better.

The two-auger air lock with the flared plugging chamber effectively maintained an air seal, but the thrust bearing mounted at the base of the vertical auger could not be effectively sealed against the entry of feed dust. Consequently, a single horizontal auger with a tapered 90° elbow to serve as the plugging chamber was tested and proved successful. All bearings were mounted outside the conveyed material area and could be effectively sealed against entry of dust.

Several auger sizes and elbow configurations were tried. The design finally chosen for the auger injector consisted of a sweeping elbow with a gradually increasing cross section that was fitted with a 2½-inch o.d. (outside diameter) auger to force material into the conveying line (figs. 1, 2, 3, 4, 5, 6, and 7). The design shown in these illustrations proved best for all-round performance. Auger sizes of 2-, 2½-, and 3-inch o.d. were tested. The 2-inch auger allowed finely ground material to bridge over it, and the 3-inch auger had a higher capacity than was needed for operation with a 2-horsepower hammer mill. Power requirements for the augers increased with speed, line pressure, and auger diameter.

The 2½-inch auger injector injects up to 2,000 pounds of material per hour into a 1-inch conveying line against a working pressure of 10 p.s.i. Approximately 1.5 horsepower is needed to operate the injector auger at a speed of 1,800 r.p.m. This size auger will inject most ground feeds. It will not satisfactorily inject whole or ground oats

or other feed containing a high percentage of fiber. Material of low density does not feed well through the auger.

It is important that the tapered elbow, which serves as the air lock, have a gradual taper and a smooth inside surface for the injected material to slide on. A rough inside surface increases the difficulty of forcing feed material upward through the injector and into an airstream. The flared plugging chamber is made as an elbow and is turned upward so that the plugging chamber is kept full by gravity to maintain an effective seal even when no new material is being injected.

The 2½-inch auger injector with a 1-inch conveying line is well matched to the output of a 2-horsepower hammer mill. Increasing the size of the conveying line to 1¼ inches, with a corresponding increase in conveying air volume, allows the 2½-inch auger injector to convey the output of a 3-horsepower hammer mill—about 3,000 pounds per hour. Conveyor capacities in excess of 3,000 pounds per hour require larger injectors and larger pipe.

The configuration of a successful 3-inch injector is shown in figure 8. This injector and auger fit the hopper and base described for the 2½-inch injector. However, approximately twice the volume of air is required to satisfactorily convey material in a 1½-inch conveying line than in a 1-inch line. For satisfactory performance, a 1½-inch conveying line requires a minimum of 45 c.f.m. of air. The 3-inch injector auger requires about 30 to 50 percent more power than the 2½-inch auger because it has 52.4 percent greater screw cross section. The 3-inch auger will inject 6,500 pounds per hour at 1,800 r.p.m. against 7 p.s.i. and require 1.4 horsepower. Specific power requirement of the injector varies with the line pressure and conveying rate. U.S. patent No. 3,169,799 has been granted on the auger injector, additional design details for which are shown in figures 9, 10, and 11.

Several automatic feed preparation and distribution systems consisting of a 2-horsepower hammer mill and a medium-pressure pneumatic conveyor equipped with an auger injector are now in operation in the United States, and all of them are performing satisfactorily. The conveyor and auger injector developed in our laboratory have been field tested and have performed extremely well. The only wear, which appeared soon after the unit was placed in operation, was abrasion of the auger flighting caused by the feed material. This rapid wear was stopped by coating the face of the last convolution of the injector auger with a layer approximately one-sixteenth of an inch thick of Stellite hard surfacing material (fig. 12).

It is essential that the front bearing of the injector auger be sealed to prevent the entry of feed dust into the bearing race. The front bearing is mounted on the rear of the supply hopper and should be a cast flange ball bearing. The mechanical seal of most ball bearings is inadequate protection against the entry of dust. The positive air pressure within the supply hopper will force fine dust particles into the bearing race unless an additional seal is used. A piece of ½- by ½-inch asbestos string packing gland fitted into the recess of the flange bearing between the bearing and the supply hopper wall can be formed into an effective seal by tightening the flange bearing mounting bolts. (See figure 10.) This seal prevents dust entering the bearing race from the supply hopper.

Distribution pipe

Ground feed may be conveyed in 1-inch pipe that is smooth inside and resistant to abrasion. The design of the distribution pipe should include a summation of pressure loss calculations for the system. The number of turns should be kept to a minimum. Elbows with a radius of 7 inches or more are desirable where possible to keep pressure loss to a minimum. The pressure loss in four 90° turns with a 7-inch radius is approximately equivalent to the loss in 100 feet of straight pipe.

The best estimate of pressure losses in a medium-pressure pneumatic conveying system, assuming the use of a 1-inch i.d. pipe, a feed flow rate of 1,200 pounds per hour, and an airflow rate of 25 c.f.m., is as follows:

	Loss p.s.i.
100 feet of system length	1.5 to 2.0.
90° 7-inch radius elbow	0.4 to 0.5.
10 feet of vertical lift	0.3.
Feed injector and entrance losses	1.5.
Flow diverter valve	0.3 to 0.6.

More detailed design information for computing pressure loss is shown in figures 13 and 14.

Couplings

Quick couplings provide a convenient manual way of directing the flow of feed from the conveyor to one or more discharge points (fig. 15). When the operator wants to select a new ration for delivery, he can transfer the discharge of the conveyor to the desired location in a few seconds by use of a quick coupling.

Automatic valves can also be used to direct the flow of feed to one or more discharge points, but the valves and control system cost about $300 per station. The automatic three-way valve shown in figure 16 can direct the flow of feed and air to one or two distribution lines. A series of these valves can direct feed to any desired number of discharge points.

Electrical control

The electrical controls for the medium-pressure pneumatic conveying system and feed grinder are relatively simple and provide fully automatic operation for a single station (fig. 17). The wiring diagram and legend for the electrical control system are shown in figure 18. Use of the quick coupling previously described and of an electrical interlock to connect the proper remote pressure switch to the mill control system enables the operator to deliver feed automatically to any number of stations.

The completed automatic feed preparation and conveying system consists of three basic units—conveyor, mill, and controls (fig. 19). The modules of this system assembled into a working unit are shown in figure 20.

Operation of the medium-pressure pneumatic conveyor is comparatively simple. The conveyor output is connected to the desired conveying line, and the system is started. Automatic controls start the compressor and injector motor. The grinder then starts after a preset time delay or when the line pressure drops to a satisfactory level, whichever occurs last. The system continues to process and convey feed until it is stopped by the mill-mounted interval timer or by the remote pressure switch, whichever is controlling the system. If the system runs out of an ingredient or if pressure in the conveying line rises above a preset limit—usually 2 p.s.i. above the normal line pressure when conveying to the most distant point (not above 15 p.s.i. for most compressors)—the input of material is stopped by stopping the mill. If a motor is overloaded and an overload relay is tripped, the mill and the conveyor are stopped and will not automatically restart. If only the mill (input of material) is stopped because of a high line pressure or because an ingredient is depleted, it will restart automatically if the fault is corrected within a preset warning timer limit—usually 2 minutes or less. The warning timer operates any time the mill motor relay is open and when the system should be operating (interval time "on" or pressure switch "on"). When the warning timer completes its time cycle, the conveyor is stopped, and the mill and the conveyor are prevented from restarting until the fault that caused the system to stop is corrected, and the warning timer is manually reset.

A medium-pressure pneumatic conveyor that uses an auger injector is an ideal way to transport feed automatically from the processing unit to the distributor. It uses only a nominal amount of electricity. One hundred pounds of feed can be mixed, processed, and transported 400 feet for only 0.5 kilowatt hour of electrical energy.

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FIGURE 1.—Auger injector air lock developed for use on farm feed distribution system.

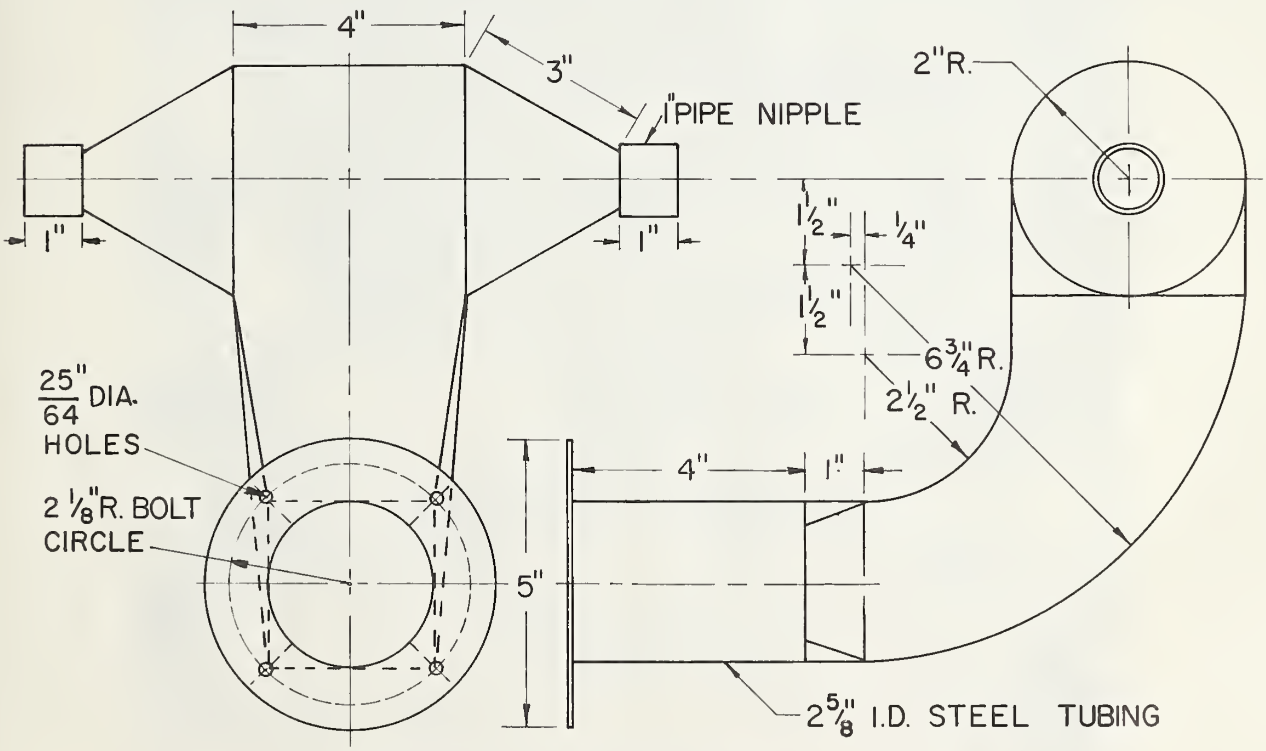


FIGURE 2.—Design for a 2½-inch auger feed injector.

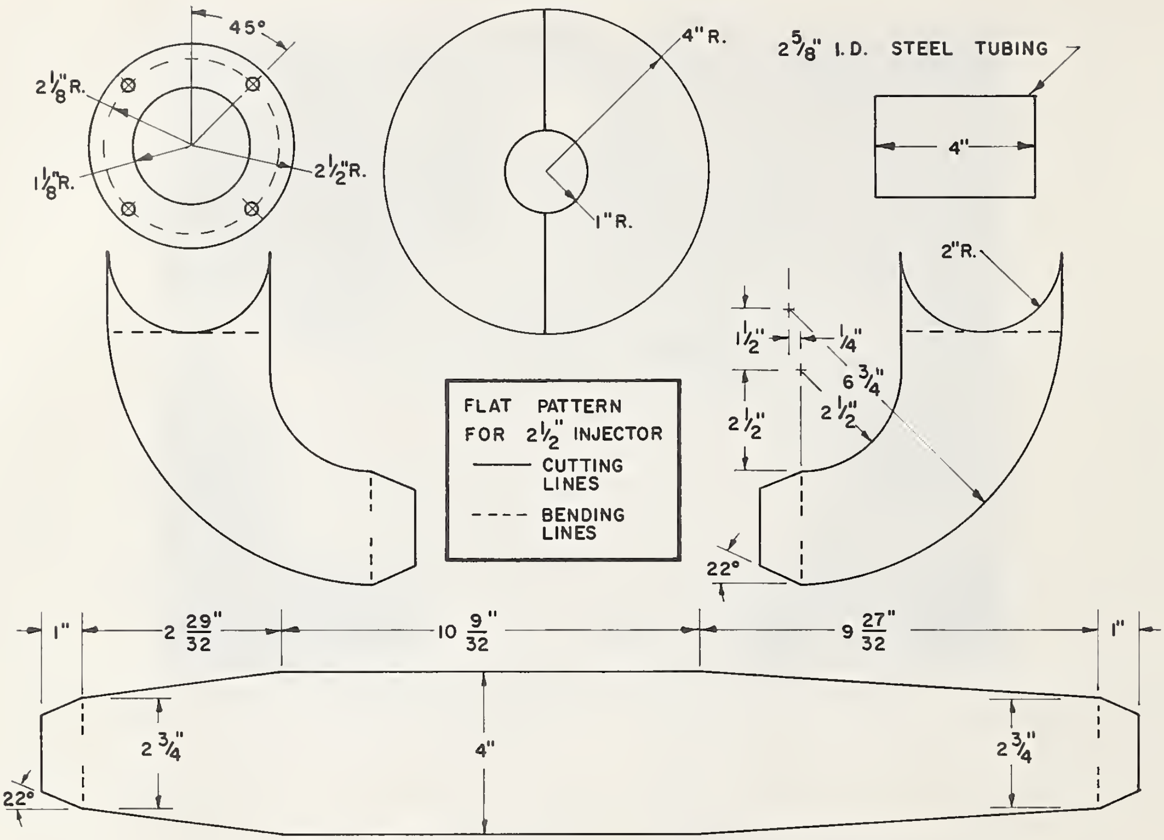


FIGURE 3.—Pattern for a 2½-inch auger injector housing.

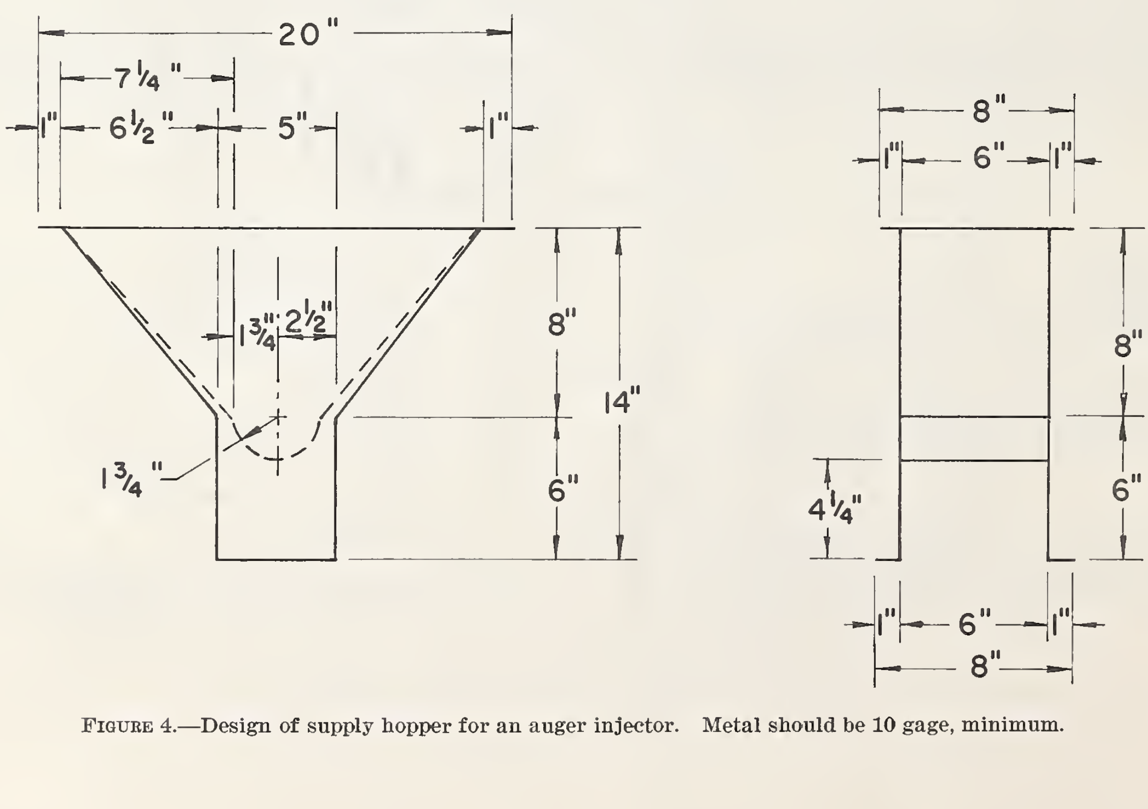


FIGURE 4.—Design of supply hopper for an auger injector. Metal should be 10 gage, minimum.

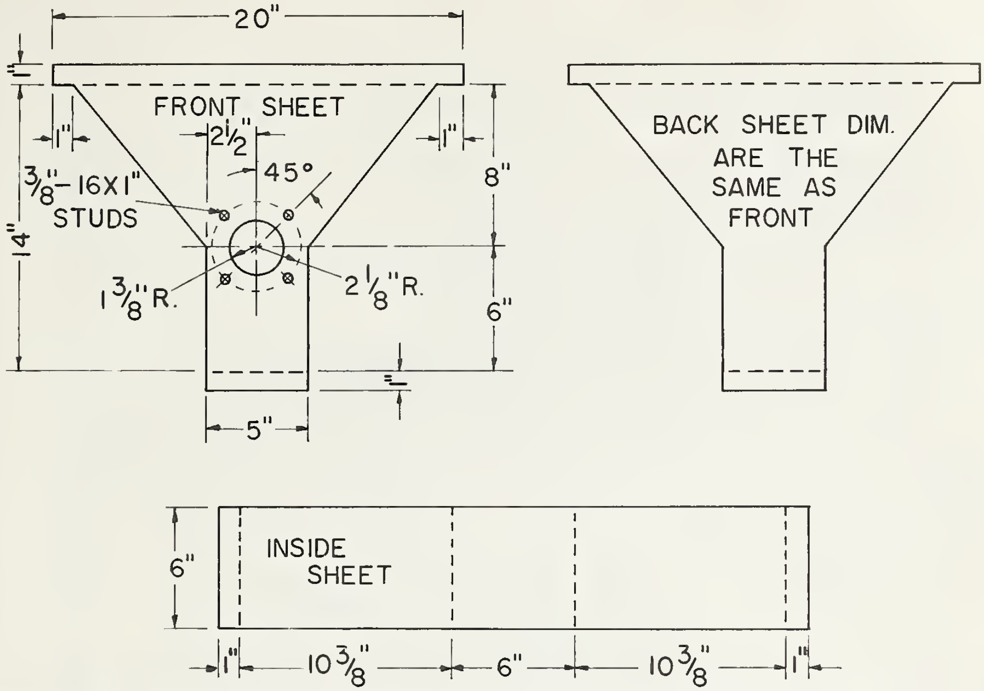


Figure 5.—Pattern for the auger injector supply hopper. Metal should be 10 gage, minimum.

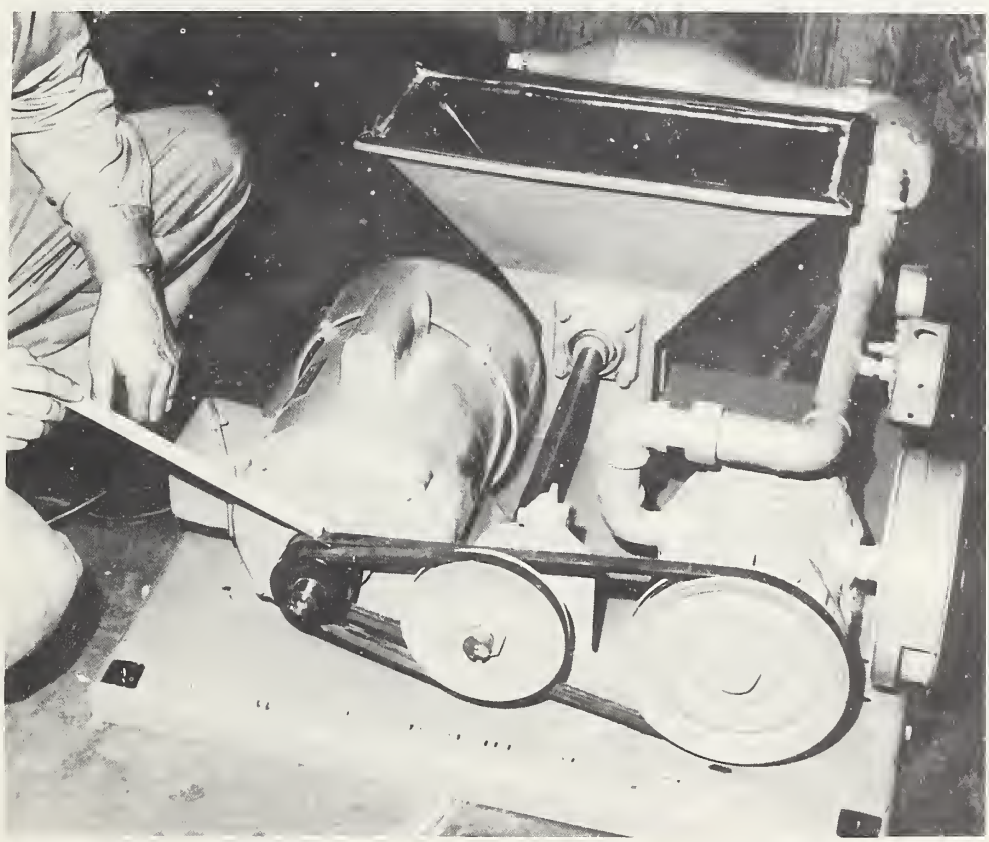


Figure 6.—The auger injector and air compressor are powered by the same motor. Motor and compressor can be moved to adjust belt tension.

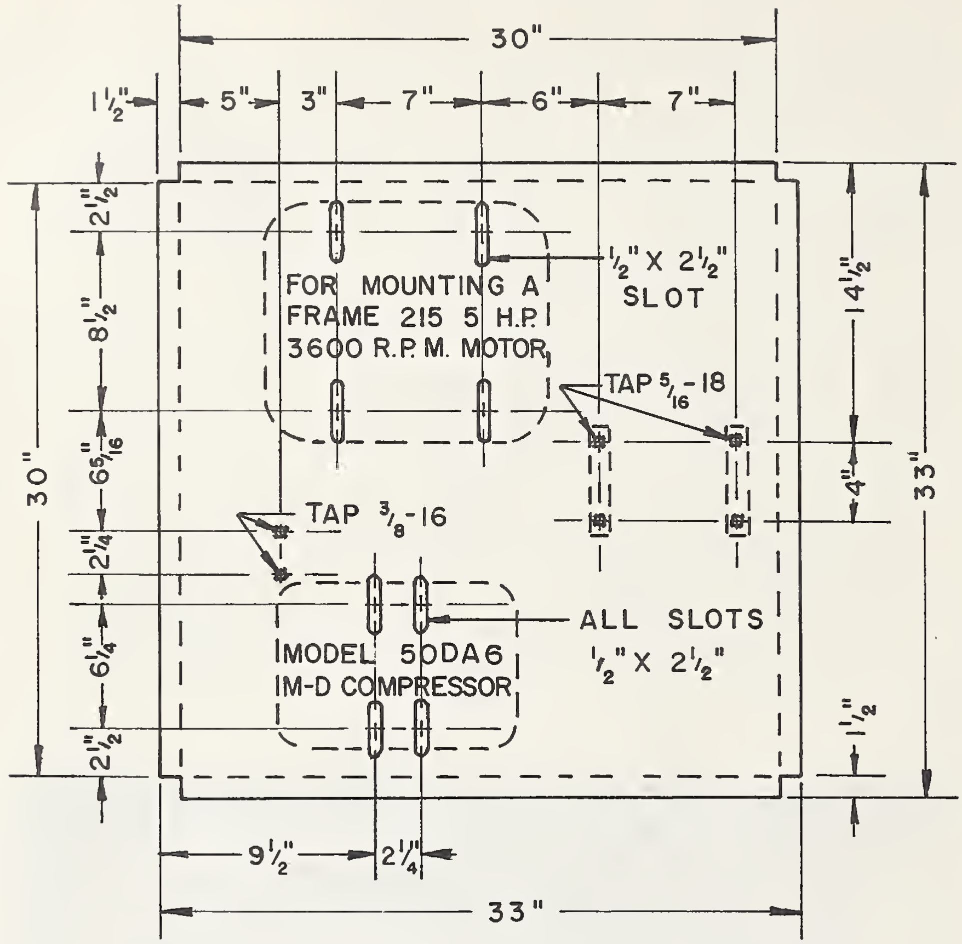


FIGURE 7.—Plan of mounting base for auger injector and components.

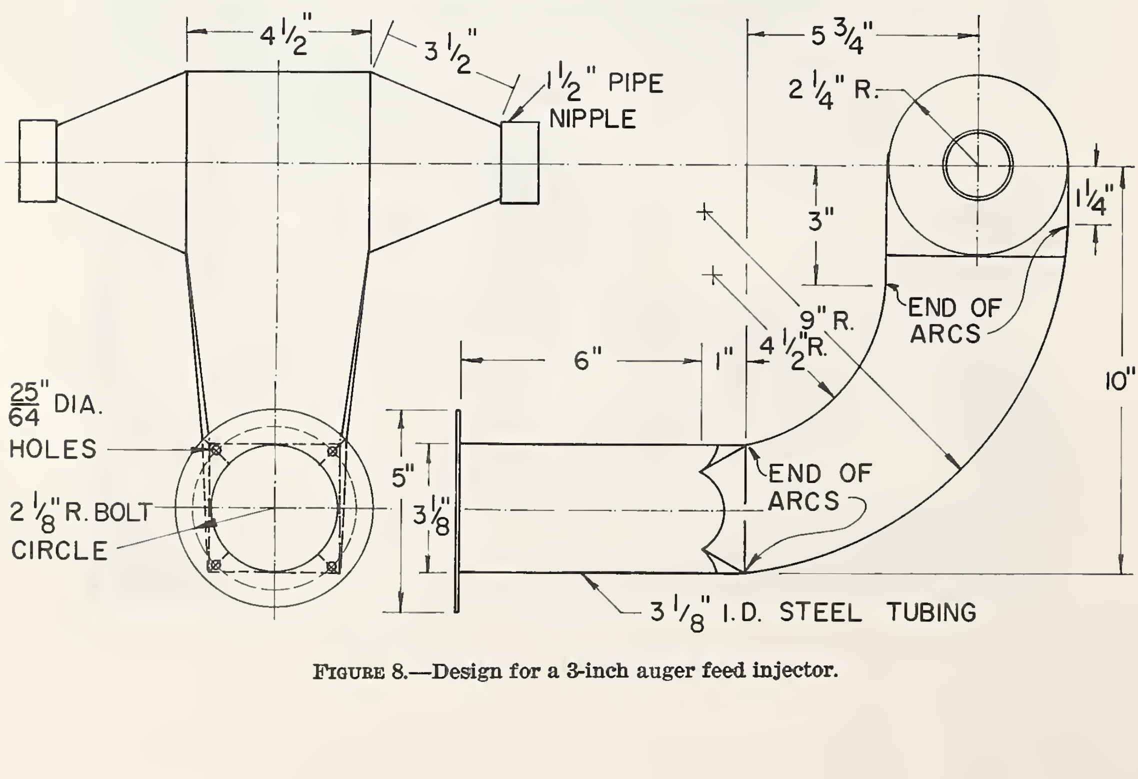


FIGURE 8.—Design for a 3-inch auger feed injector.

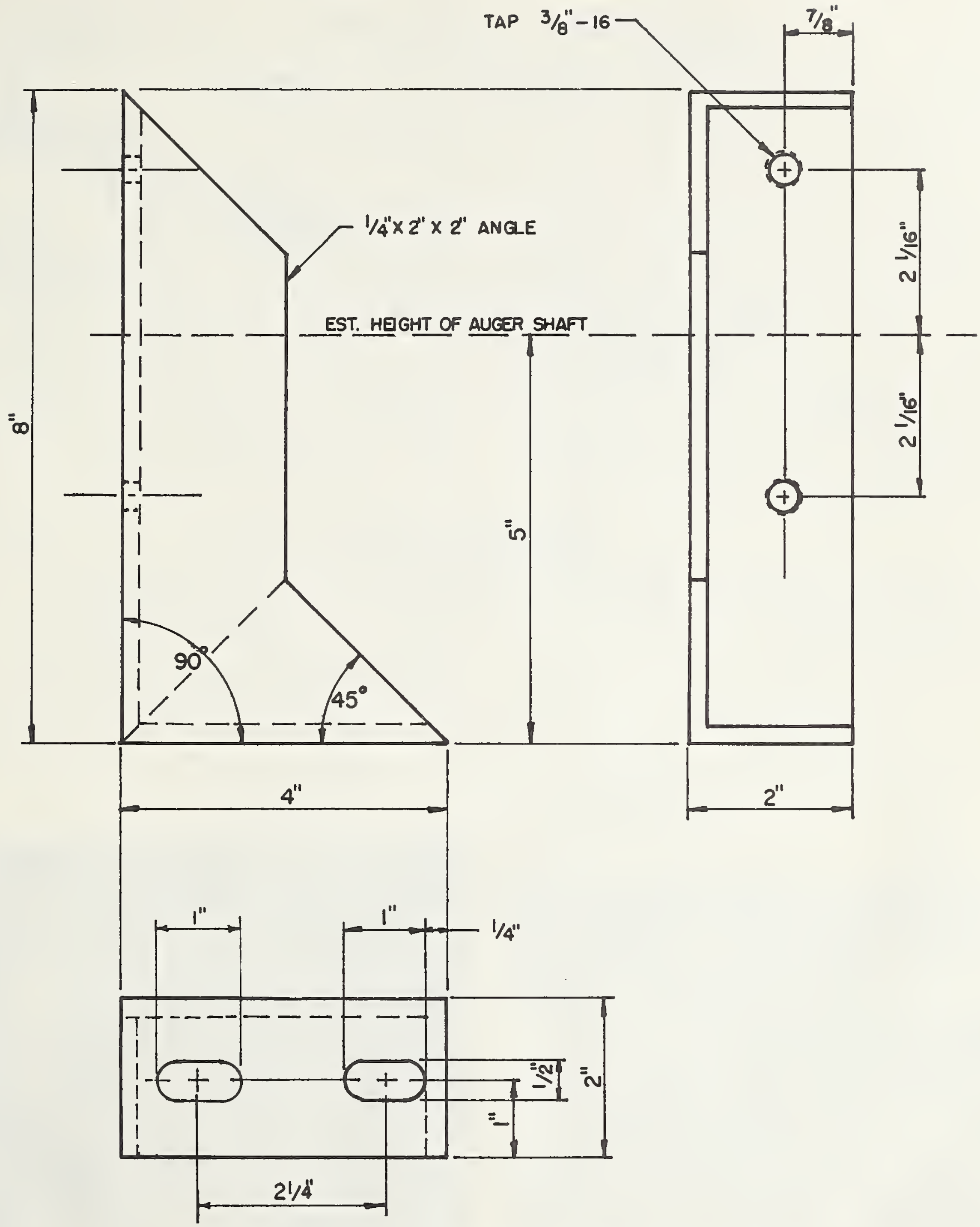


FIGURE 9.—Rear pillow block bearing support for injector auger shaft.

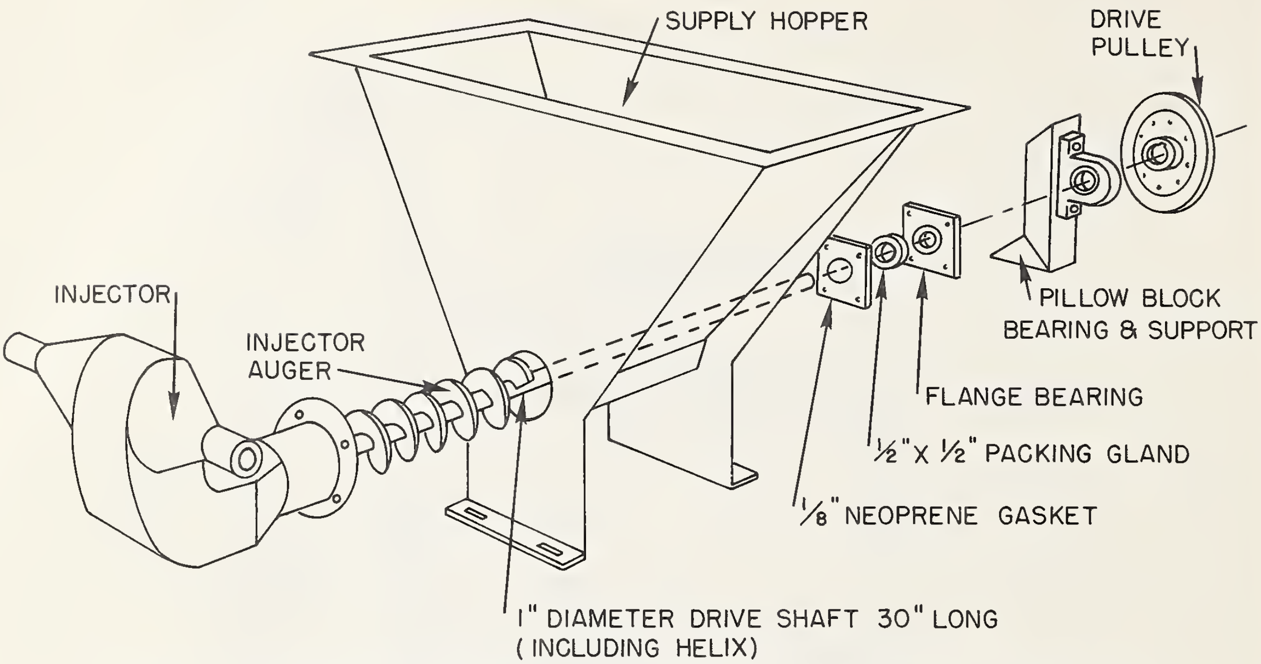


FIGURE 10.—Exploded view of auger injector and supply hopper showing location of component parts.

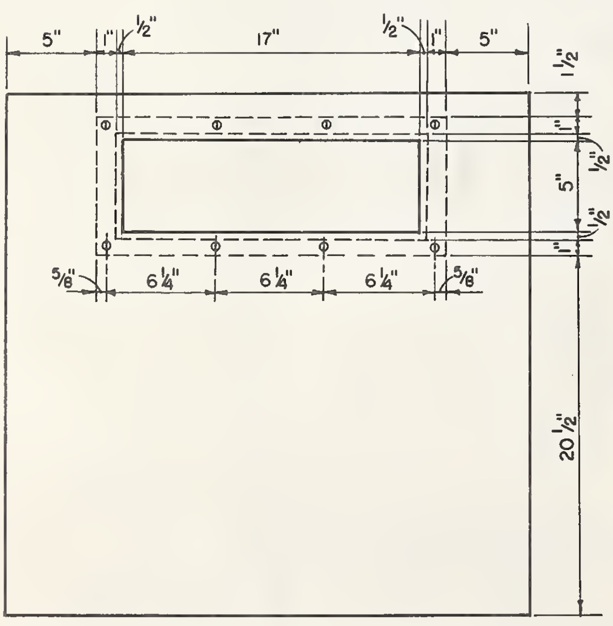


FIGURE 11.—Top cover plate of pneumatic conveyor unit. Metal should be 10 gage, minimum.

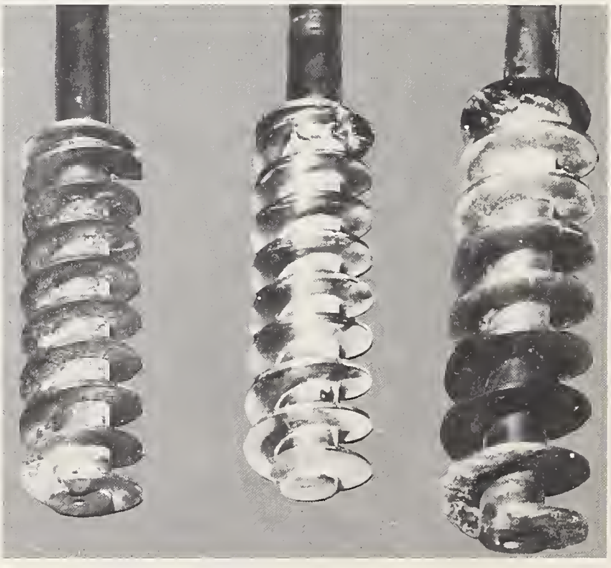


FIGURE 12.—The auger on left has not been used; the one in center has conveyed 100 tons of feed and is severely worn; the one on right has been given a surface coating of Stellite on the end convolution.

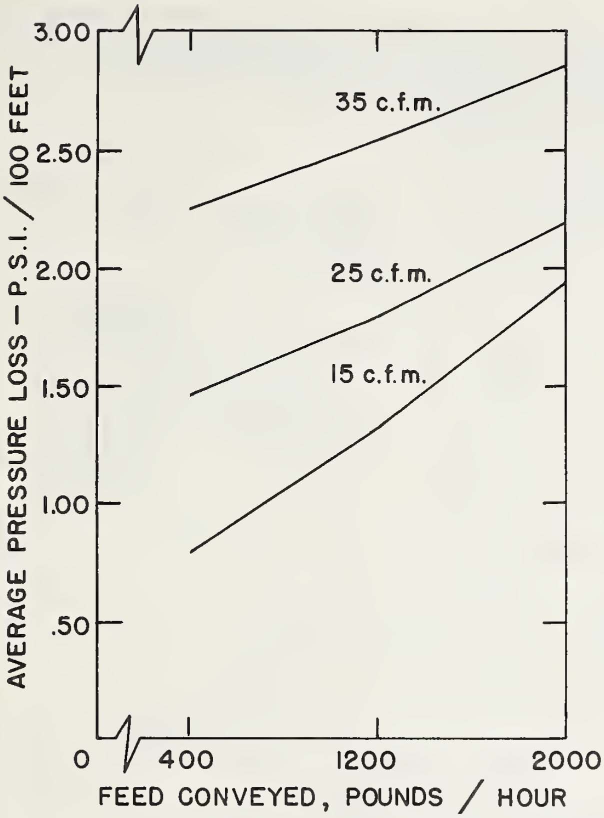


Figure 13.—Pressure losses in straight 1-inch i.d. pipe.

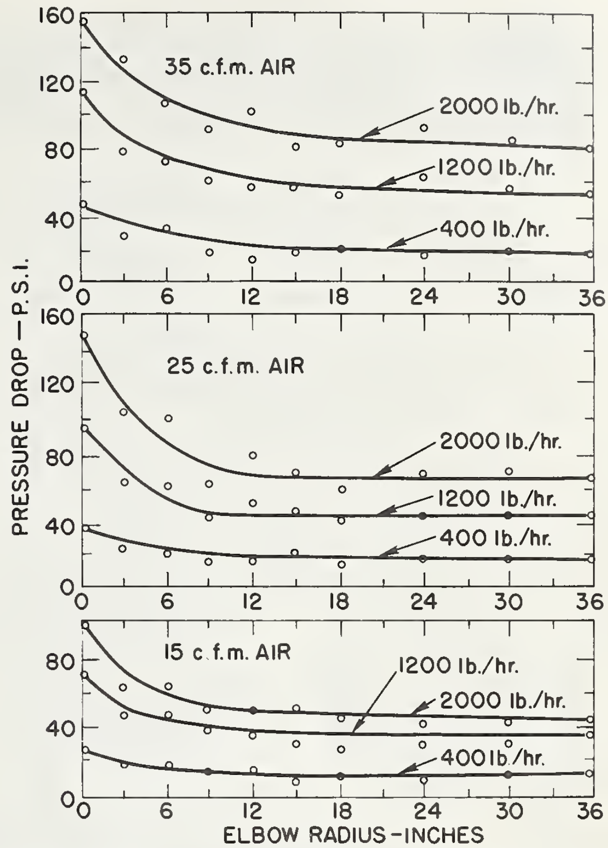


Figure 14.—Pressure drop in 1-inch i.d. elbows for nine combinations of air volume and feed rate.

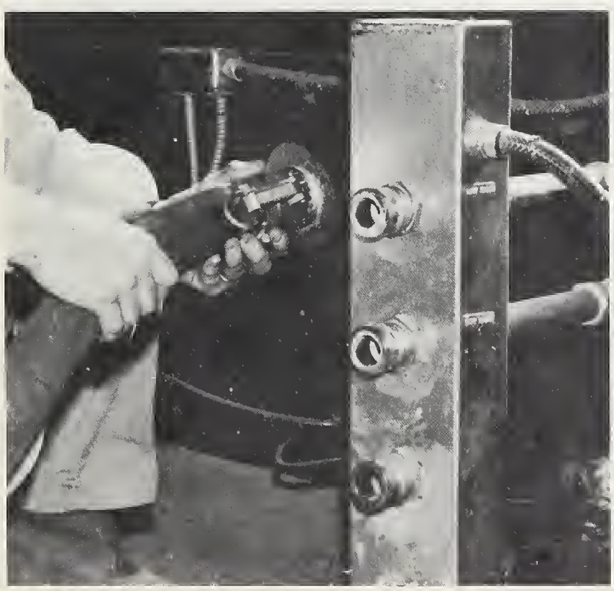


Figure 15.—Quick couplings for routing feed from conveyor to several different locations.

Figure 16.—Air-operated electrically controlled pinch valve. The rubber valve liners are closed by air pressure applied between the outer steel casing and the liner.

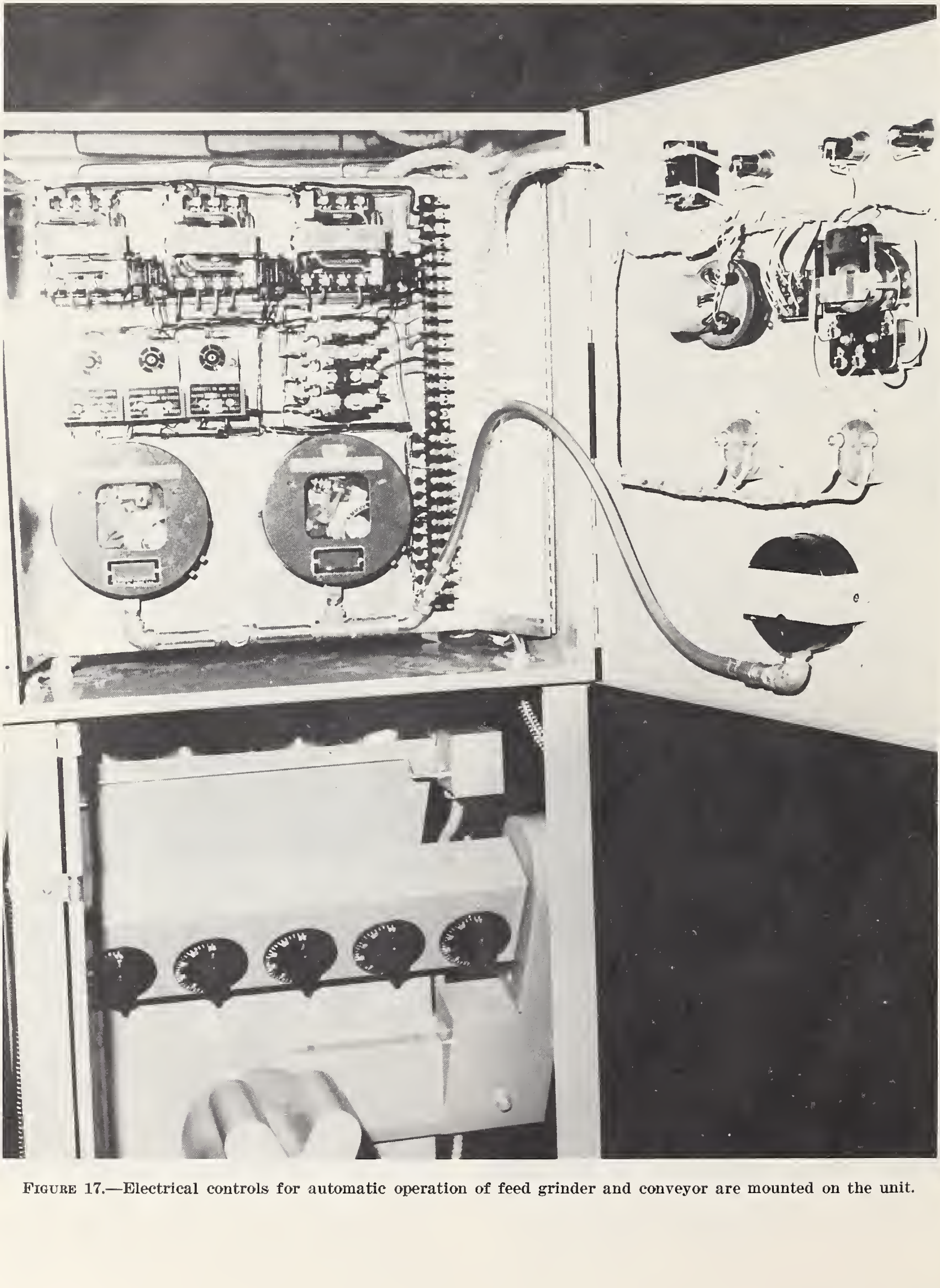
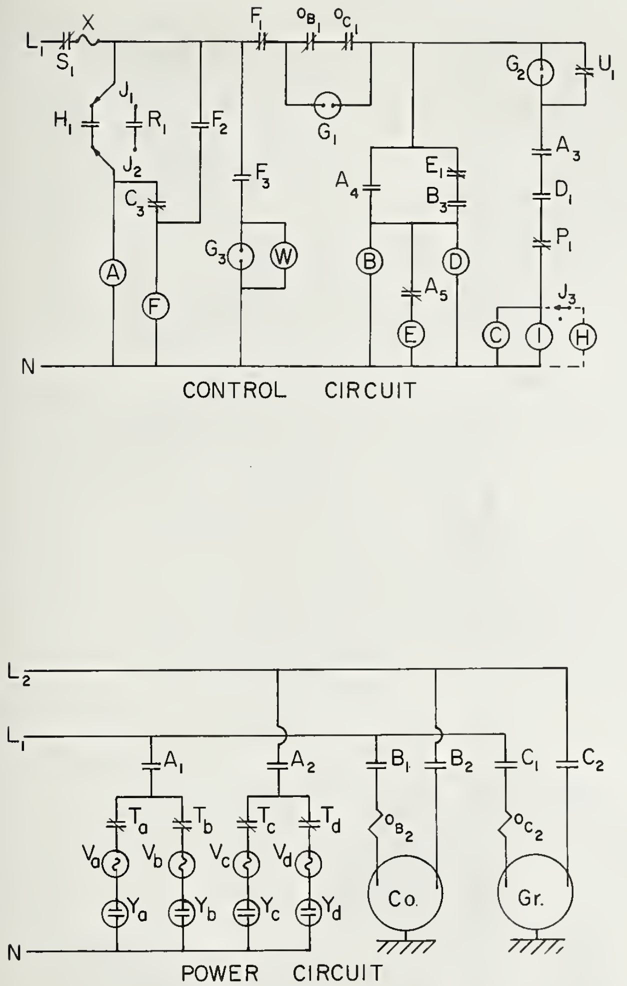


FIGURE 17.—Electrical controls for automatic operation of feed grinder and conveyor are mounted on the unit.



LEGEND FOR WIRING DIAGRAM

A—Relay, supply auger motors
B—Relay, compressor motors
C—Relay, grinder motor
D—Time delay (sequence start; 1-minute adjustable; single pole double throw)
E—Time delay (sequence stop; 1-minute adjustable; single pole double throw)
F—Time delay (warning stop; 2-minute adjustable; single pole double throw)
G—Glow lamps (110 V) NE 51 in series with 18K ohm resistor. G_1, motor overload; G_2, feed meter; G_3, warning signal.
H—Timer (2-hour interval; spring wound or electric)
I—Timer (totaling)
J—Toggle switch (manual, automatic; three pole double throw)
O_1—Motor overload contacts (normally closed)
O_2—Motor overload heaters
P—Pressure switch (conveyor air line; normally closed; single pole single throw)
R—Pressure switch (distribution bin; normally closed; single pole single throw)
S—Toggle switch (stop, reset; normally closed; single pole single throw)
T—Pressure switch (supply bins; normally closed; single pole single throw)
U—Pressure switch (bin safety; normally closed; single pole single throw)
W—Warning light (exterior)
Gr—Grinder motor
Co—Compresors motor
L—Line
N—Neutral
V—Fuse or circuit breaker, supply auger motors
X—Fuse or circuit breaker (control circuit) (10A)
Y—Outlet (supply auger motors)

FIGURE 18.—Wiring diagram for automatic feed distribution control system and legend.

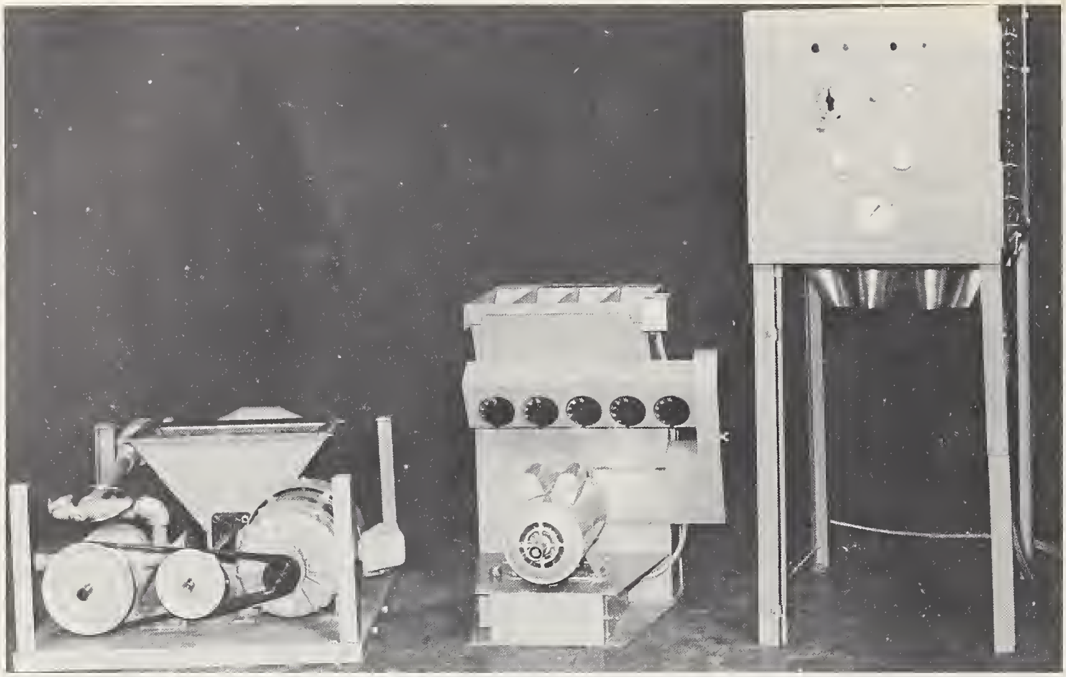


FIGURE 19.—Basic modules of the automatic feed preparation and conveying system are: Left, conveyor; center, mill; and right, controls for mill and conveyor.

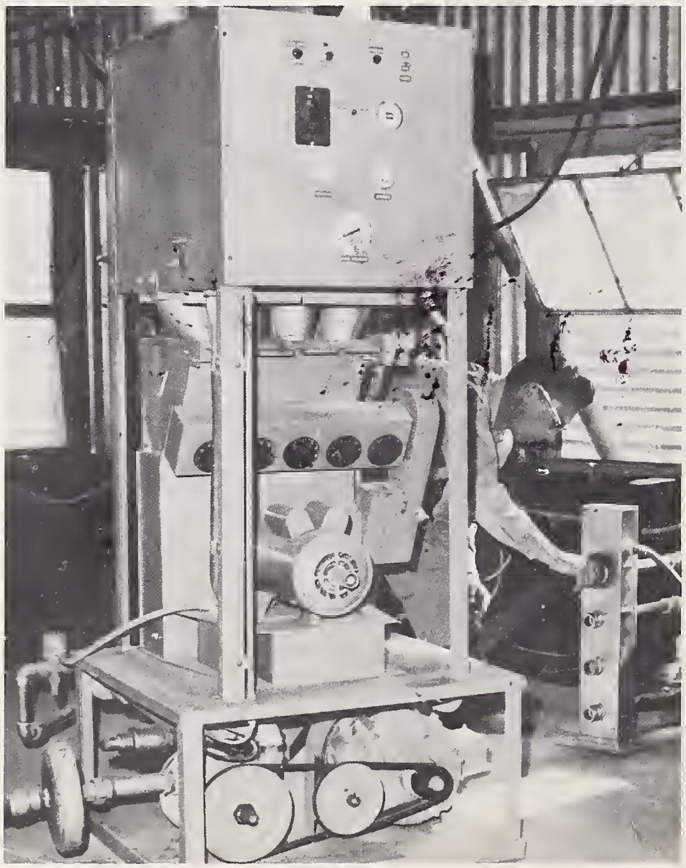


FIGURE 20.—Basic modules assembled into a compact feed preparation and conveying system capable of automatic control.

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